# Advanced Railroad Wireless (ARW)

## Using “PTC” as a foundation for ARW

January 2014

SkyTel - W. Havens

“SkyTel” means Skybridge Spectrum Foundation, Telesaurus Holdings GB LLC, Environmentel LLC, Verde Systems LLC, Intelligent Transportation …LLC, and V2G LLC. Warren Havens is President of these companies.

This partial, public version is filed in FCC docket 11-79, January 1, 2014.

This is filed in this docket for purposes stated by the FCC, and in response to recent ex parte presentations by some railroads’ that implicate SkyTel, SkyTel’s ATMS licenses, our offers of AMTS spectrum to railroads, and the public interest the FCC indicates in opening and conducting this docket.

## PTC since 2008, PTC radio systems, asserted spectrum shortage, etc.

SkyTel directly submitted, and commissioned submissions from Ron Lindsay (his own views) presentations on PTC in this FCC docket 11-79. Those, and easily accessible public materials and research, show that:

- *PTC wireless does not need much spectrum. There is little data to be passed.*
- *There is no PTC wireless system plan of any substance, to date (with essential components, including defined applications, grades of service, data capacity needed, resultant wireless coverage and capacity needed, types of radio tech to be used, spectrum needed, system and architecture alternatives, etc.* Not surprisingly, railroads do not seek radio equipment that make sense- for wider channels and spectrum efficiencies.*
- *Railroads were mandated to implement PTC, by a general Congressional Act, but it is an unfunded mandate that is resisted. Assertions of lack of radio spectrum is one means to resist …*
- *… at least to slow implementation, and in the delay, seek funding, etc. SkyTel entities have a plurality of 217-222 MHz available for PTC, but not once has any railroad responded to our initiated proposals, over many years. Some railroad have issued to Skytel requests for information, interest, and not-fully-defined proposals. SkyTel has always responded.** (We have, at times, offered spectrum at little or no financial cost (and only modest other cost, clearly in the public interest), or at appraised value less a discount, and in any case not above fair market value (which we know: all sales of geographic AMTS spectrum have been by us).*
- *These assertions are for the most part false. SkyTel can provide details to the FCC (some public, and some confidential), if the FCC would like to have them, to compare to assertions of some railroads.*
- * E.g., not one railroad has, in public (per our substantial research), or in private communications with us, reflected basic knowledge of fundamental major differences in many of these factors, e.g., the major difference in performance per amount of spectrum by use of a large spectrum block vs. separated narrow channels, and use of modern wider band technologies. Some of this is discussed below.
- *** SkyTel's responses are timely and well within the fair market in economic terms, contract language, etc.:* If railroads had *current* interest and capability (funds, authority, a serious PTC plan, etc.), the FCC would have seen assignments or leases. *Our conclusion is that the public agency railroads in this case are not "ready buyers" in a "market" situation. This appears to be, as it related to these railroads, a government to government fight (federal vs. state-local), and it does not support a proper market environment.*

Re: PTC since 2008, PTC radio systems, asserted spectrum shortage, etc. (continued)

*As indicated on the preceding page, in our substantial experience with PTC wireless and public agency railroads, the railroads are subject to an expensive, burdensome, unfunded mandate.*

*PTC wireless by itself does not make sense. This is plain now, and will come to haunt those who avoid.*

*But what makes sense is* ***Advanced Railroad Wireless (ARW)****, that leverages the mandated PTC, to provide an order of magnitude- plus in improvements over PTC in applications, capacity, future viability, benefits-to-cost, integration with commercial wireless on trains, etc.*

*We present ARW below. It is being implemented worldwide. The US should not get further behind.*

*This PTC fixation is a diversion ('polly wanna PTCracker') but it can be used as a platform for ARW.*

*ARW will use highly spectrum efficient tech, systems and architecture. These are currently available.*

*Contents*

1. Re - *Contiguous* spectrum blocks and benefits in VHF including 200 MHz.
2. Re - *Advanced Railroad Wireless*.
3. Re - SkyTel entities' 217-220 MHz, M-LMS 904-910 MHz, and 35-43 MHz.
   - SkyTel obtained these for nationwide smart transport, energy and environment systems, which can include *ARW*.
   - Persons fixed on PTC are not in a position to consider or pursue *ARW*, as far as we understand. It may even be seen (falsely) as a threat.
   - We present *ARW* as part of our nationwide plans, including to persons in various federal agencies Congress, and other public entities.

- 1 -

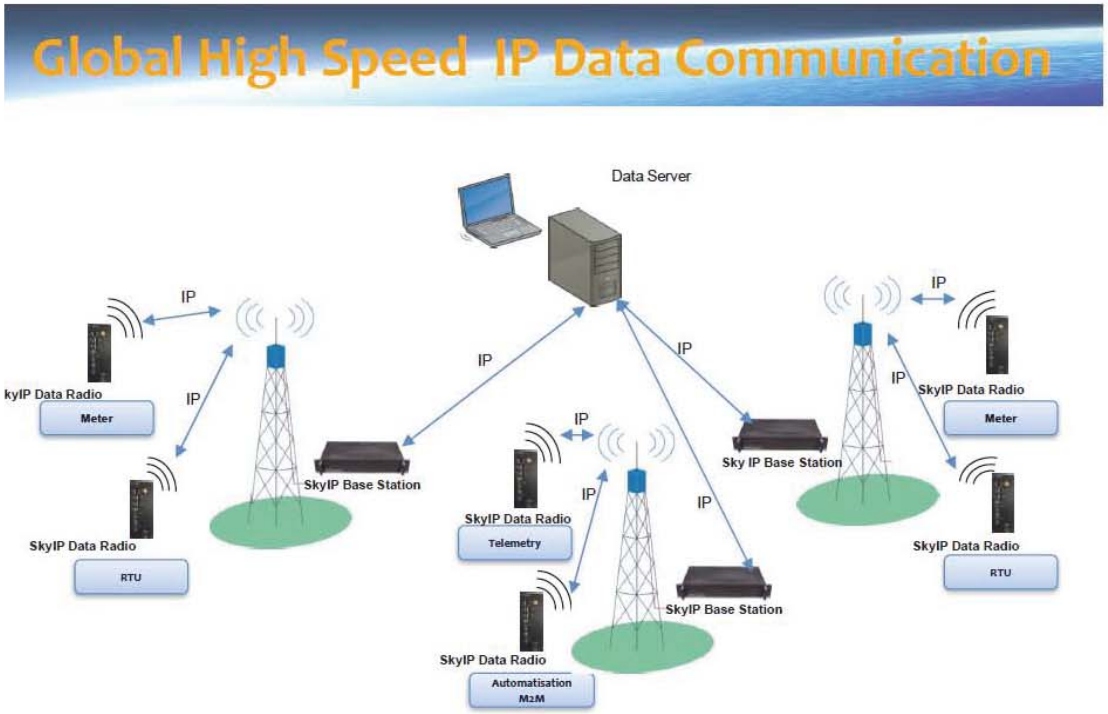
*Contiguous*

spectrum blocks

and benefits in VHF including 200 MHz

*SkyTel*

*This is illustrative, not hereby a suggested technology or product.* This is an example of an wider-band mission-critical VFH-range radio and system. *Note the comparison below between 12.5 kHz and 100 kHz bandwidth as implemented in this radio.* The SkySkweep company informed SkyTel (no relations between the companies) that they can radios in lower 200 MHz, upon commercial arrangements.
Below is from: http://www.skysweep.com/index-2.html




## The *SkySweep* IP over radio system devices:

**SkyIPR-1 Telemetry Data Radio**
- Frequency band 146-174 MHz or 400-512 MHz
- TX power max. 2 W
- 2 x RS232
- 1x RJ45 10/1000 ethernet
- DIN-RAIL-mounting
- Temperature range -20°C - +70°C

**SkyIPR-2 Mobile Station**
- Frequency band 146-174 MHz and 400-512 MHz
- TX power max. 20 W
- 2 x RS232
- 1x RJ45 10/1000 ethernet
- Temperature range -20°C - +70°C

**SkyIPBS Base Station**
- Frequency band 146-174 MHz and 400-512 MHz
- TX power max. 20 W
- 2 x RS232
- 1x RJ45 10/1000 ethernet
- 19 inch enclosure
- Temperature range -20°C - +70°C

## Technical Data

- **Frequency range**

| | |
|---|---|
| VHF Band | 146 – 174 MHz |
| UHF Band | 400 – 512 MHz |

- **TX Power**

| | |
|---|---|
| Telemetry Data Radio | max. 2 W |
| Terminal / Base Station | max. 20 W |

- **Modes**

DMO (P2P point to point and P2M point to multipoint)
Trunking operation (IP Router und Bridge).

- **Channel bandwidth and max. data rates**

| | |
|---|---|
| 6.25 kHz | 21 kbit/s |
| 12.5 kHz | 52.8 kbit/s |
| 25 kHz | 126.7 kbit/s |
| 50 kHz | 253.4 kbit/s |
| 100 kHz | 506.8 kbit/s |
| 200 kHz | ~1 Mbits |

*Note:*
*SkyDR IP data radio specifications* ***(preliminary)*** *might be subject to change due to product innovation and improvements without prior notice. This version: March 2013*

# FlexNet-One

## Compact Vehicular Wide Band V/UHF Software Defined Radio

### CONNECTIVITY AND MOBILITY

By integrating FlexNet-Waveform, the Thales FlexNet-One V/UHF SDR equipment offers high data rate transmission on the move, transverse communications and mobility management which strongly improve the connection between the users from headquarters to small action units.

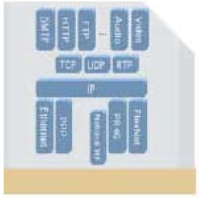
FlexNet-One brings to the users an increased level of services such as voice (digital or VoIP), data (short messages, formatted messages, file transfer), image and video transmission.

### FLEXIBILITY

Based on an open architecture, compliant with Software Communications Architecture (SCA) international standard, and a powerful programmable hardware platform, FlexNet-One ensures enhanced functionality, expandability and waveform portability accommodating future technology or requirement upgrades with ease.

### INTEROPERABILITY

The radio can be immediately reconfigured to provide interoperability with the PR4G standard and is open to host other standard waveforms (MIL-STD, Stanag) and national waveforms (Panther, SEM 93…) with national specificities.




### SYSTEM INTEGRATION

By using and combining IP compliant protocols, FlexNet-One:

- Greatly improves the system integration in Local Area Networks or other tactical networks.
- Easily interfaces with standard applications such as Battlefield Management System, Information System or other IP standard applications.

With regard to vehicle integration, high performances co-site filters are provided to improve vehicular installations and communication system performances.

### AFFORDABILITY

With its compact format, Flexnet-One is a tailored and affordable SDR solution for battlefield vehicle.

In addition with the new ad hoc networking waveform, FlexNet-One can be easily integrated in all kind of mobile vehicles. A form/fit compatibility of the worldwide operated Thales PR4G vehicular tactical radio greatly facilitates the installation.

FlexNet products are joint developments of Rockwell Collins and Thales, the worldwide leaders in SDR technology.

## FEATURES

### GENERAL CHARACTERISTICS

- Mobile ad hoc networking: self-organizing, self-healing, automatic routing upon mobile nodes
- Open architecture, full SCA compliant to ensure waveform portability and accommodate customized requirements and upgraded functionality
- Embedded or external high grade encryption including customer specific encryption
- Easy integration with IP networks and applications

### PERFORMANCES

- **Frequency range:** 30 - 512 MHz
- **Bandwidth:** 25 kHz (V/UHF), 300 kHz, 1.25 MHz and 5 MHz (UHF)
- **Power output:** 50 W VHF and UHF
- **Data rate:** up to 64 kbps (VHF), up to 6 Mbps (UHF)
- **High performance VHF and UHF co-site filters**
- **Automatic power output** and duty cycle adaptation to optimize spectrum occupancy and power consumption
- **Internal or external GPS**

### ENVIRONMENTAL CHARACTERISTICS

- Operating temperature: -40 °C to +70 °C
- Shock and vibration in accordance with MIL-STD-810E

### INTERFACES

- Audio for combat net mode
- Ethernet 10/100 Mbps
- V24/V28 RS232 - PPP
- SNMP remote control

### INSTALLATION

- Power supply: 28 V DC nominal
- Accessories: compatible with PR4G accessories (mount, antennas, handset, power supply, cables…)

*This is illustrative, not hereby a suggested technology or product.*

This is an example of an wider-band mission-critical VFH-range (and higher) radio and system.

This is from Rockwell Collins and Thales, designed for military use.

But the same tech can be used in non-military radios (excluding some features not needed outside military use, such as SCR): narrow up to wide band channels, multiple bands, and the noted advanced characteristics, etc.

Without use of wider contiguous channels, one cannot use radios that use such wider channels, and support higher data rates and more advanced applications (and greater total system capacity), etc. But with such wider channels, the system operator can always use more narrowband channels and modes (dividing the wider contiguous spectrum into any number of more narrow channels).

It is best to start with a contiguous block for current and future purposes.

*This is illustrative, not hereby a suggested technology or product.*

## FullMAX: Broadband Wireless for Mission Critical Industries

OFDMA for max. coverage and reuse

Low latency network with QoS

Mobile Data @ 75 Mph

Configurable DL/UL capacity

EAP Authentication AES128 Encryption

# FullMAX MS4000 Specifications

### PHY

| | |
|---|---|
| PHY | OFDMA with support for all Sub 1 GHz frequencies and narrow and wide channels |
| Adaptive Modulation & Coding (AMC) | QPSK ½ to 64QAM ¾ |
| FFT Size (No. of Subcarriers) | 128 FFT |
| Avg. Remote Data Rate | 0.35 to 1.75 bps per hertz based on CINR and AMC |
| Sample Channels<br>200 kHz Channel<br>500 kHz Channel<br>1 MHz Channel | Remote Avg. Date Rate<br>70 kbps to 350 kbps<br>180 kbps to 870 kbps<br>380 kbps to 1.8 Mbps |
| TDD Frame Synchronization | GPS synchronization for multi-base station operation |
| Rx Sensitivity | -107 dBm |
| Permutations | Partial Use of Subchannels Uplink and Downlink |

### RF

| | |
|---|---|
| Frequencies Supported | 40 MHz to 958 MHz (5 kHz steps) |
| Channel Sizes | 200 kHz to 5 MHz configurable |
| Duplex Method | TDD |
| Tx (effective transmit power) | Up to 10 Watts (40 dBm) Adaptive Power Control |

### Services

| | |
|---|---|
| QoS types / Classes of Service | Best Efforts<br>nrtPS<br>rtPS<br>ertPS<br>UGS |
| Security | Authentication EAP<br>Encryption AES 128 |

### Mechanical / Electrical

| | |
|---|---|
| User Interfaces | 10/100 BaseT on RJ-45, RS232 |
| Voltages | DC (9 to 36 VDC) |
| Size / Weight | 11.02" x 7.87" x 2.80" (9 lbs)<br>30 cm x 20 cm x 7 cm (3.75 kg) |
| Temperature (F/C) | -22° F to140° F (-30°C to +60°C) |
| Humidity | 95% humidity for 96 hours, 55% average humidity |

### Network Management

| | |
|---|---|
| Management Protocol | SNMP, SSH<br>Console Command Line Interface (CLI) |
| Software upgrades | Over the Air (OTA) |
| Remote management | FullMAX NMS SNMP |

2452 Embarcadero Way, Palo Alto, CA 94303
www.fullspectrumnet.com
(888) 350-9994

Specifications and Performance subject to change

Full|Spectrum

*Re: less guard channels needed for 1 contiguous block vs. many blocks.*

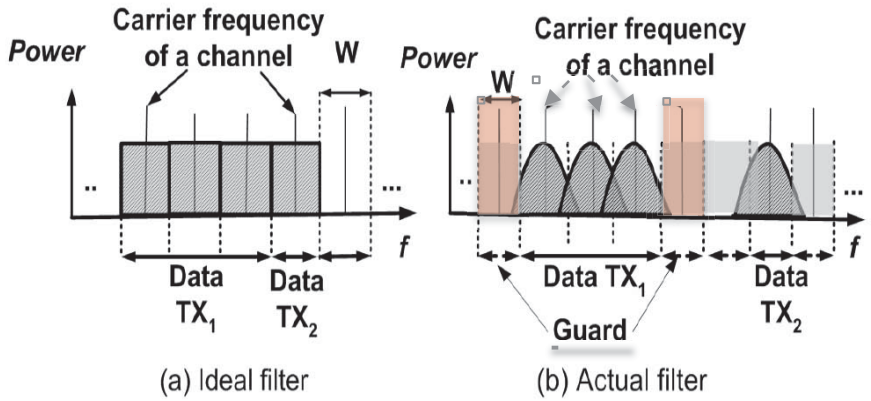



Figure 1: Ideal vs. actual transmission filters.

The diagrams on the left depict guard bands in "actual" (real world) radio-systems, on both ends of a number of frequencies used for data transmission (a channel).

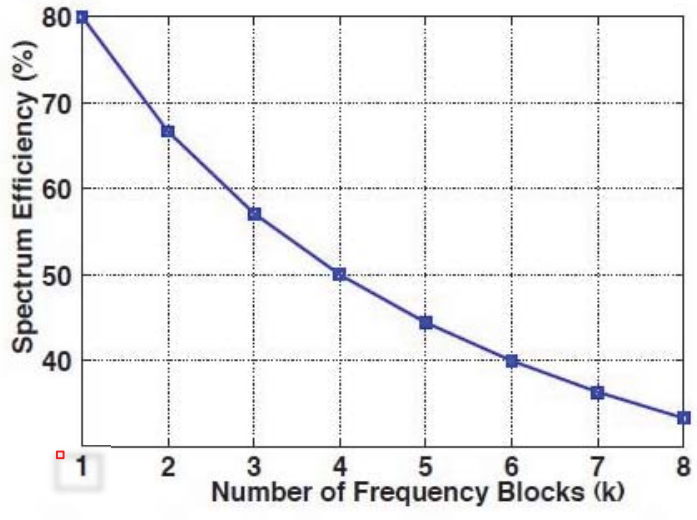



Figure 2: Number of required channels vs. number of blocks ($m = 8$).

" As a numerical example, assume that a given … transmission requires m = 8 data channels. Assume that the best 8 channels are non-contiguous and one guard channel on each side of a data channel is available. According to the greedy scheme, this … transmission requires 16 guard channels, which results in spectrum efficiency of 33%. Here, spectrum efficiency is defined as the ratio of the number of data channels and the total number of required data-plus-guard channels.

" On the other hand, if 8 adjacent data channels are available (i.e., one [contiguous] frequency block), the transmission will require only 2 guard channels. This results in spectrum efficiency of 80%. Figure 2 shows the total number of required channels as a function of k for m = 8.

Source of charts and quoted language: "Design and Evaluation of an Efficient Guard-band-aware Multi-channel Spectrum Sharing Mechanism,"
Copy at: www2.engr.arizona.edu/~krunz/TR/**guardband**_aware_Feb2011.pdf

Regarding VHF range guard bands, and further on contiguous blocks.

Honeywell | Aerospace

Products & Services | Newsroom | Contact | Follow the Aero

AIR TRANSPORT | BUSINESS AVIATION | DEFENSE | HELICOPTERS | SPACE | PRIORITIES | ABOUT

Home > Products > Navigation Systems > Radio Navigation > VHF Transceivers

Like | Share | Tweet | +1

# VHF Transceivers

Applies to: Air Transportation & Regional

VHF Radio has long been the primary means of voice communications between aircraft operating in civilian airspace and Air Traffic Control. VHF Radios operate in the 118-137 MHz frequency band. Each VHF channel occupies 25 kHz so there are 760 channels that can be assigned to provide coverage in the various air space regions. The type of modulation used for voice communications is Double Side-Band Amplitude Modulation (DSB-AM) in which the voice audio from the microphone modulates the VHF carrier frequency. This type of analog modulation occupies about 7 kHz out of the 25 kHz channel assignment. The excess bandwidth in the channel is used as a guard-band to reduce the level of interference to adjacent channel assignments. Thus in today's architecture of the Air Traffic Control VHF network, sectors in the same general area may be assigned very closely spaced VHF channels.

Key Benefits

Platforms & Applications

*Product Support*

- Aircraft Options and Upgrades
- Asset Availability
- BGA System Configurations
- Download Catalogs
- Product Brochures
- Repair and Overhauls
- Returns
- Sales Bulletins
- Spare Parts


VHF Radio has long been the primary means of voice communications between aircraft operating in civilian airspace and Air Traffic Control.

VHF Radios operate in the 118-137 MHz frequency band. Each VHF channel occupies 25 kHz so there are 760 channels that can be assigned to provide coverage in the various air space regions.

Here is an example of a mission-critical VHF* radio transceiver (transmit-receive radio) that occupies 25 kHz.

The data modulation uses "about 7 kHz"" leaving 18 kHz guard band spectrum: 9 kHz on each side.

While many factor affect suitable width of guard bands, SkyTel's proposal allows effective guard bands on both ends of the proposed contiguous spectrum block: 10 kHz on one end, and that or greater on the other end. SkyTel will use these only in a way that "guards" the railroad's use of the assigned block. The railroad will fully control adjacent-channel issues intra-block (whether it uses narrow or wider channels).

---

* VHF is 30-300 MHz, and includes 217-222 MHz.

- 2 -

# Advanced Railroad Wireless

(Read above slides first to understand below)

Advanced Railroad Wireless (ARW) Initial Study (SkyTel)

The study involves use for NEC passenger railroads' operations, including MTA's operations, of wide radio frequency spectrum blocks in the following radio services and frequency bands:

(a) the "AMTS" Service in 217-220 MHz (in greater amounts than in ),

(b) the "M-LMS" Service in the lower 900 MHz (in multi-MHz bandwidth),

(c) the "DSRC" Service in the 5.9 GHz range (in 10 MHz or more bandwidth), and

(d) the "Paging" service licenses in the 35 and 43 MHz VHF "Low Band" range.

SkyTel entities, SkyTel, holds FCC licenses in all these services and bands except DSRC: these holdings are described and mapped in slides below.

DSRC is the "sister" band to M-LMS. These are the two compose the "Intelligent Transportation System Radio Service" established by the FCC under Part 90 subpart M of its rules. DSRC at 5.9 GHz is for short-range and M-LMS in lower 900 MHz is for long-range wireless coverage. AMTS in lower 200 MHz is for still longer-range and more-robust coverage, and the 30-40 MHz Low Band spectrum is for super -long-range and –robust coverage. In mission-critical wireless over wide areas and corridors, redundancy in coverage and diversity in bands is especially important.

The ARW Study will involve use, without limitation, of the following (some of these further discussed below an in the Appendix-1 Slides:

(a) LTE and LTE-like technology, products and systems in these spectrum bands.

(b) Integration with commercial broadband wireless systems as used by these railroads ("RRs") passengers and staff, with a high level of "firewall" and other controls.

One of the goals is to achieve no-gap highly-secure high-speed wireless communications for both train operations, and for passengers—with no gaps, including for passengers by covering the coverage gap in locations and times of the commercial wireless systems and WiFi systems that provide varying levels of service along the railroad corridors and stations. The lower range spectrum described above (900 MHz and below), placed into service at fixed based stations of the railroads, can achieve this.

(c) Two-way wireless communications, as well as one-way broadcast wireless such as by use of "Digital Radio Mondiale" ("DRM") employing some of the 35-43 MHz spectrum, and some of the AMTS lower- 200 MHz spectrum.

(d) High-accuracy Positioning, Timing, and Navigation ("PNT") using certain currently available technologies and systems including "Network RTK." This is critical for many applications, both for railroad operations, and for passengers, including passengers with disabilities.

(e) Coverage above ground, and through underground railroad facilities and tracks (subways), with no gaps.

SkyTel projects, for railroad operations by themselves, over order of magnitude increase in per-station, per-link, and overall system capacity-- at only small additional capital and operational expenditures-- as compared to implementation of PTC-only wireless systems on lower 200 MHz. There would be a multiple of wireless capacity in addition, also at only modest additional costs, for service to passengers via the function indicated above.

The goals, radio spectrum, technologies, equipment, systems, and means to implement the advanced railroad wireless systems outlined herein are all currently availably. Like systems are already deployed and others are being planned in various major metropolitan areas of the World, but with the spectrum indicated above, the US NEC passenger railroads can have a superior system. The Appendix-1 Slides demonstrate some of these, and all of these are easy to verify. It is important to look outside of much of the current thinking and trajectories of parties not aware of these, or who would not benefit from implementation of the indicated goals of this NEC Study.

The implementation SkyTel has in mind on the spectrum bands and bandwidths noted above would not only increase by a large multiple the wireless data capacity for train operations, and thus increase safety, security, efficiency, etc., but also provide high-speed wireless access into the trains for passengers. This would be easily combined with on-board commercial and WiFi wireless to the extent those are available in many locations and train-movement conditions.

Use of dedicated mission-critical-grade radio spectrum and systems described above will provide constant and more reliable wireless access for passengers than by use of only commercial and WiFi wireless. Gaps in coverage and reliability is a major detraction in wireless access, and the just noted improved high-speed wireless assess to passengers should increase ridership and revenues, etc.

(Cont'd) Advanced Railroad Wireless (ARW) Initial Study (SkyTel)

The train operations would always have priority use of the multi-band wireless systems, and in emergencies would preempt capacity used for passengers in non-emergency situations. This would be another benefit.

As general references, the following are papers SkyTel commissioned relevant to this NEC Study outline:

A paper by Dr. Nishith Tripathi on the use of LTE in M-LMS in 900 MHz (where we have 5+ MHz bandwidth available), and in AMTS in 200 MHz:
http://www.scribd.com/doc/104580013/LTE-for-M-LMS-900-MHz-for-Intelligent-Transportation-Systems-N-D-Tripathi-Aug-2012

A paper on the wireless for railroads by Ron Lindsey:
http://www.scribd.com/doc/53478557/Wireless-for-Railroads-By-Ron-Lindsey-April-2011

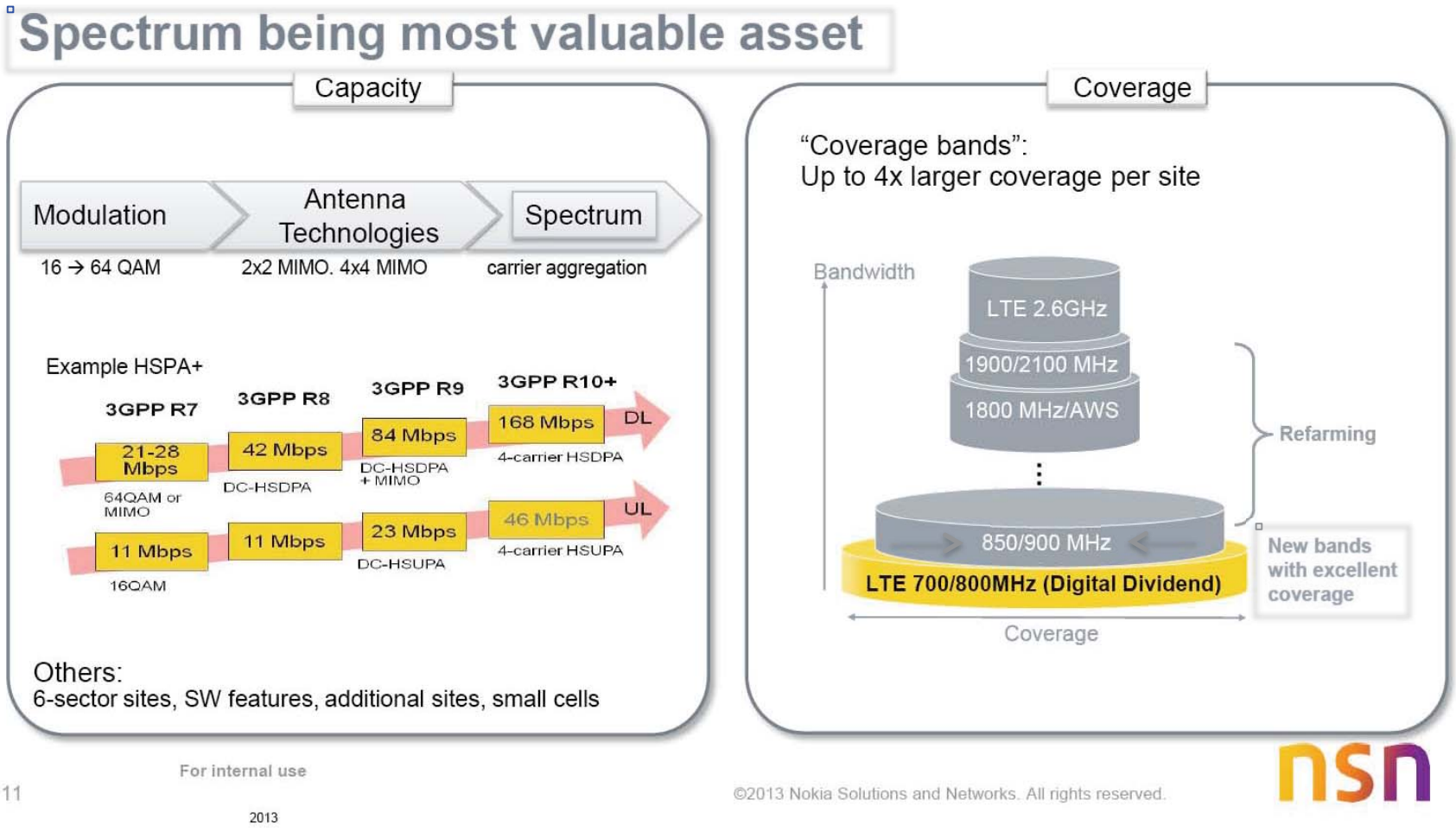
A paper by the University of California, Berkeley, Institute of Transportation Studies on ubiquitous, nationwide high-accuracy location (position, navigation and timing)
http://www.eecs.berkeley.edu/~kannanr/assets/project_loc/CHALOCBA.pdf

Slides below provide further information on this Study rationale and justification, potential technologies, etc. These are by world leading companies and authorities in advanced wireless, including advanced wireless for railroads.

SkyTel licenses. At the end, in Part 3, below are slides describing and mapping the AMTS 217-220 MHz, M-LMS 900 MHz, and 35/43 MHz licenses of ENL and the other SkyTel entities.

/ / /

From "LTE industry snapshot," by Nils Kleemann, Head MBB Solutions, APAC, Nokia Solutions and Networks. 12/9/2013




From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

Continued, same publication

# How important is to reach *population coverage* quickly?

… and where.

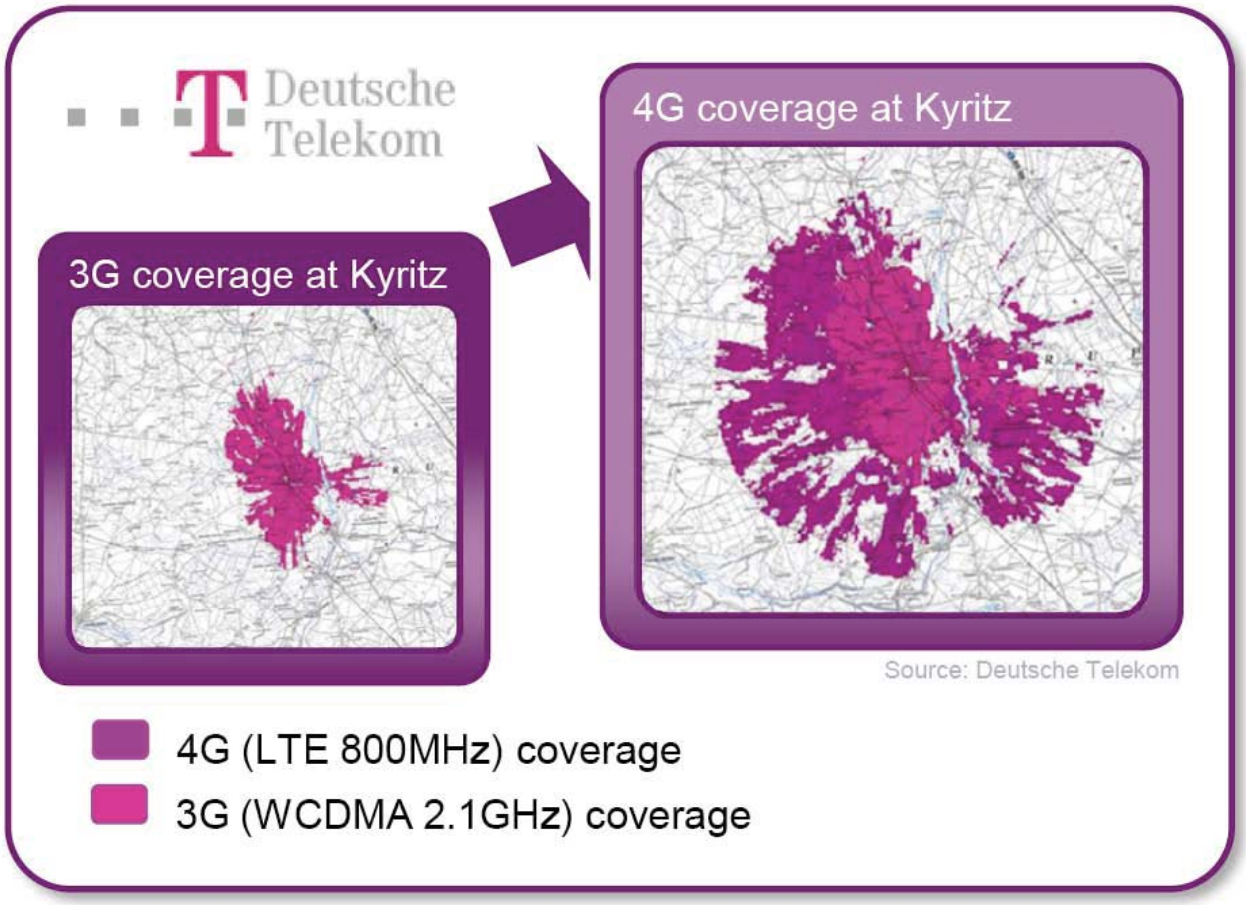
> "Coverage is just as important as speed…
>
> … when users fall out of LTE coverage zones and are switched back to 3G speeds, it is not a nice experience"
>
> *European operator*



From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

*SkyTel*

Continued, same publication



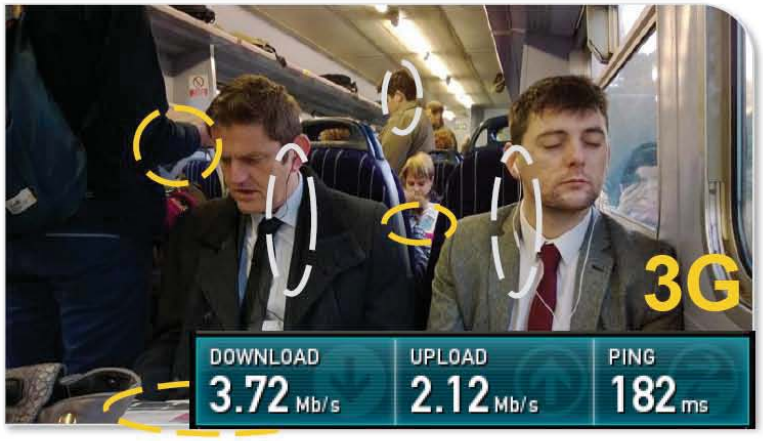

From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

Continued, same publication

**Korea:**
Long daily commutes to cities with **excellent coverage**


**UK:**
Long daily commutes to cities with **no special coverage on trains**

Three people reading **newspapers**
Three people **listening** to music/podcasts
**No one looking at their smartphone**




Everyone **looking** at their smartphone

For internal use

33



nsn

From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

*SkyTel*

Continued, same publication

# LTE's influence on Wifi


Seoul subway speedtest, October 2013
All three networks provided by same operator

EE UK, August 2013:

Since using 4G,
43%
use fewer or no public Wi-Fi hotspots (up from 37% in April)

**South Korea:**

"Why would anyone want to use public Wi-Fi when LTE is so much better?"

**Might not be everywhere**

Influencing factors:

- Cost
- Convenience
- Quality
- Public vs private Wi-Fi







From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

*From document identified below*

California High-Speed Train Project

**TECHNICAL MEMORANDUM**

**Automatic Train Control and Radio Systems: Requirements, Solutions and Radio Frequency Spectrum Challenges**
**TM 300.04**

05 May 11
Date

### 5.3.5 LTE for voice and data

LTE is a 4G wireless technology considered next in line in the GSM evolution path after Universal Mobile Telecommunications System (UMTS) / High Speed Packet Access (HSPA) 3G technologies. LTE is currently being developed by the 3GPP, aimed at evolving 3GPP's third generation system towards an all-IP network optimized for high speed data transmission.

Rather than further developing current HSPA and modulation schemes based on the Wideband Code Domain Multiple Access (W-CDMA) used in third generation UMTS cellular systems today, LTE uses Orthogonal Frequency Division Multiplexing (OFDM) as its radio access technology, together with advanced antenna technologies.

UIC's investigation into LTE to for ERTMS is planned to start in 2020; however, LTE will most likely be a commercially dominant technology before then. Furthermore, public safety agencies including Association of Public-Safety Communications Officials (APCO), the National Emergency Number Association (NENA) and the National Public-Safety Telecommunications Council (NPSTC) have endorsed LTE as the preferred technology for a proposed national broadband network for first responders in the 700 MHz spectrum band. Even though LTE has not been completely defined as of this writing, for the above reasons, LTE is a technology to investigate to support the CHSTP radio requirements.

The LTE specification provides downlink peak rates of at least 100 Mbps, an uplink of at least 50 Mbps and Radio Access Network round-trip times of less than 10 ms.

Huawei, the network infrastructure provider, has demonstrated an LTE system on board a train that has a top speed of 268 mph and averages 156 mph that covers 19.25 miles in only 7 minutes and 20 seconds. When the train first leaves the station it supports an LTE network speed of 46 Mbps, and when the train is at top speed the data speed drops to 36 Mbps.

From: http://www.hsr.ca.gov/docs/programs/eir_memos/Proj_Guidelines_TM300_04R0.pdf

From: Steffen Amundsen, "Future Rail Communication - Implementation Scenarios for LTE, June 2013

## CHAPTER 4. INCENTIVES FOR A FUTURE LTE NETWORK

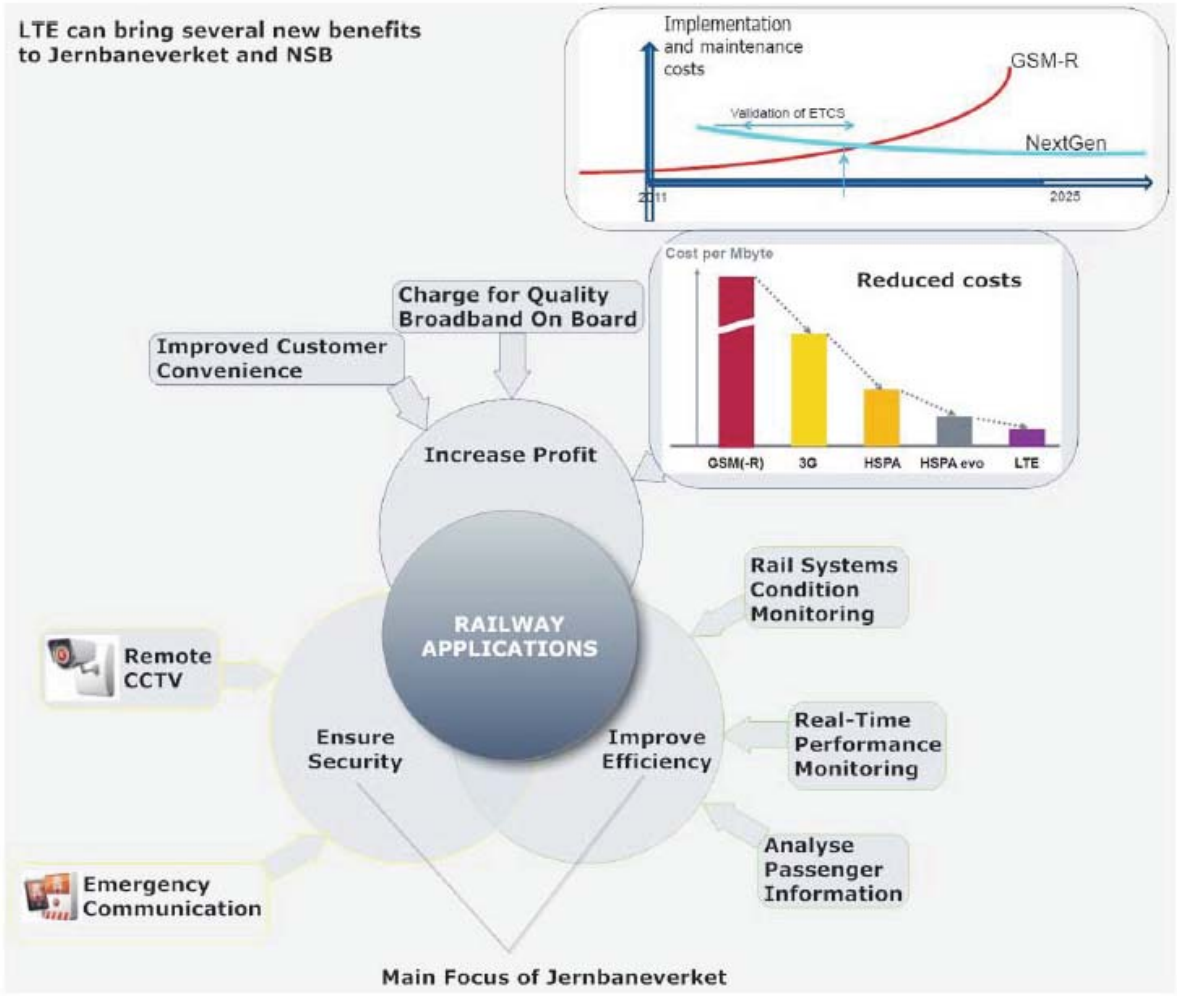



Figure 4.1: LTE Applications. [21] [22] [23] [24]

From:
www.diva-portal.org/smash/get/diva2:644985/FULLTEXT01.pdf

As outlined in the NEC plan study, we propose use of multi-MHz M-LMS spectrum with LTE, along with AMTS (as well as low band VHF we also hold nationwide) for NEC advanced railroad wireless for (i) passenger train operations, and (ii) for the foundation of full-coverage, robust high-speed wireless access for passengers.

From Nokia Siemens Networks “LTE for railways” September 2010

## Solve your business challenges and achieve environmental benefits

# Broad band on Trains



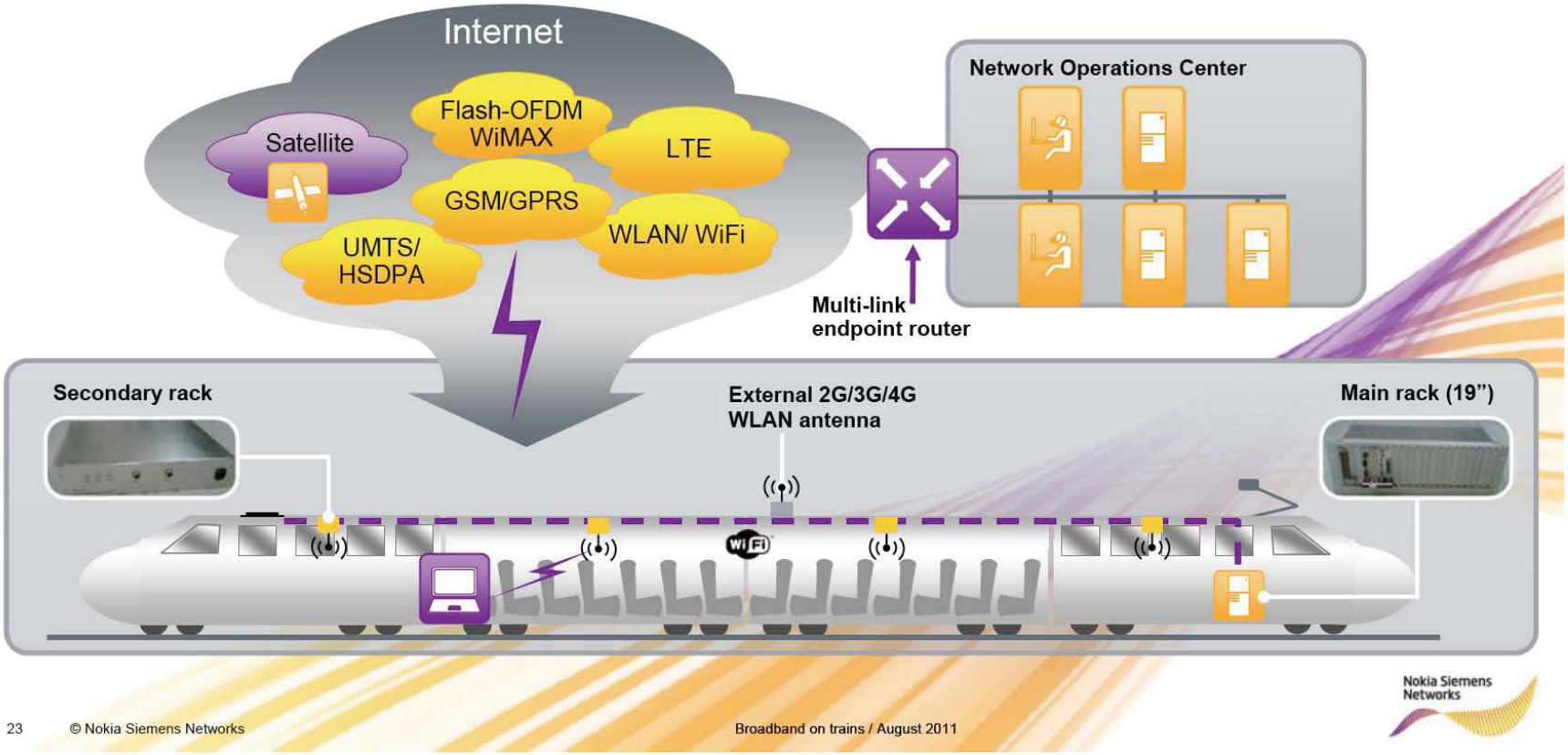


Nokia Siemens Networks

From: http://www.conferinte.clubferoviar.ro/infrastructure_development/wp-content/uploads/2012/prezentari/danijel%20kuti%20(2).pdf

From same publication

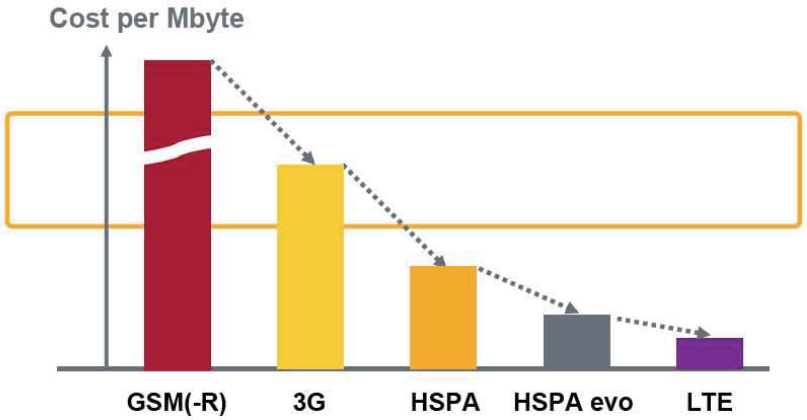
# Turnkey solution for Broadband on trains with seamless connectivity



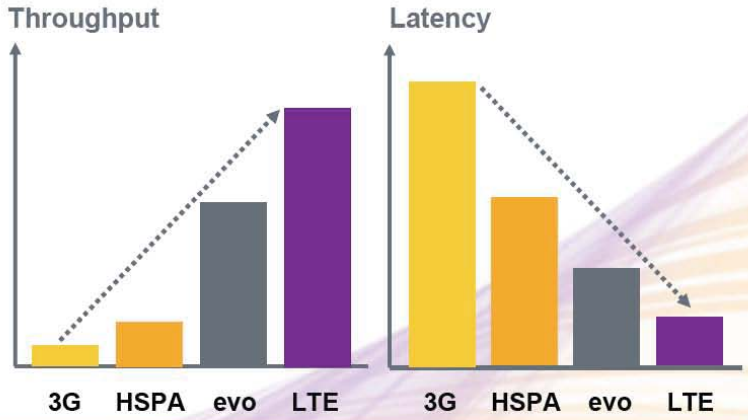

SkyTel

# LTE offers many benefits & the needed bandwidth for new services

## Lower cost for operators




## Better performance & user experience




## Investment protection & fast rollout:
## Re-use of existing sites, infrastructure, backhauling and frequency bands




*SkyTel*

From same publication

# LTE network structure: advanced configuration & supervision e.g. Self Organizing Networks

**Self-healing**
- Automated preventive corrections
- Minimized revenue loss

**Self-optimization**
- Optimal use of capacity
- Maximized revenue flow

**Self-configuration**
- Automated BTS/eNB deployments
- Faster roll-out

Quality

OPEX

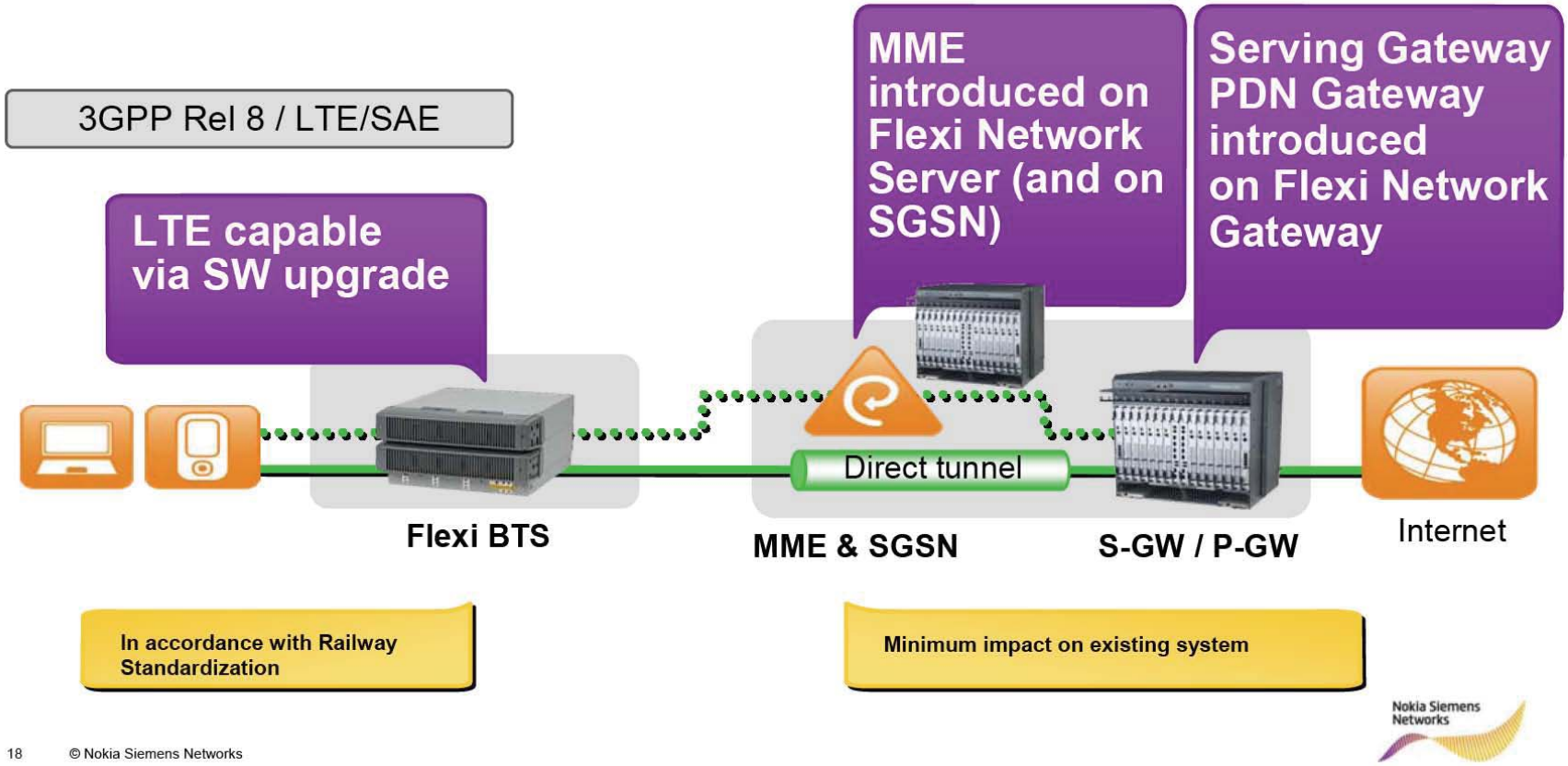



Nokia Siemens Networks

SkyTel

From same publication

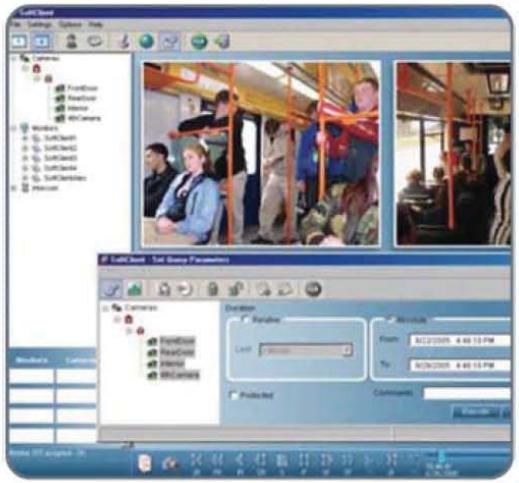
# Future evolution – smooth network evolution



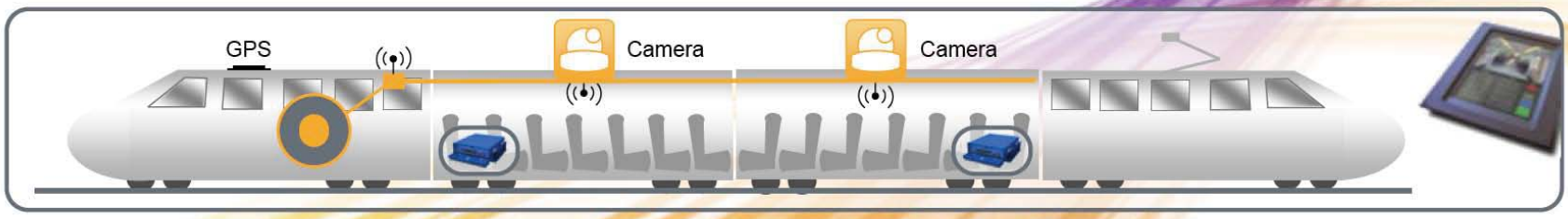

SkyTel

From same publication

# CCTV video surveillance promotes safety and security



- Real-time images
- On- and off-board recording
- Automatic video analysis and alarms
- Integrated positioning can trigger recordings
- Alarms to on-board staff or network controllers


*) CCTV: Closed Circuit Television





Nokia Siemens Networks

SkyTel

# Railway applications help you to master these challenges

WLAN/VPN to passengers**

Online ticket sales & seat reservations**

Real-time passenger information**

Entertainment** (video, audio, gaming)

Advertising**

Increase **revenue**

Railway Applications

Ensure **security**

Improve **efficiency**

Passenger counting***

Energy metering***

Train control systems ETCS level 2*

CCTV video surveillance***

Train diagnostics & monitoring***

Cargo & object tracking***

Fleet network management***

Application based on *) GSM-R; **) Broadband on trains; ***) both





Nokia Siemens Networks

From same publication

# Travelers prefer non-stop broadband Internet experience via WLAN

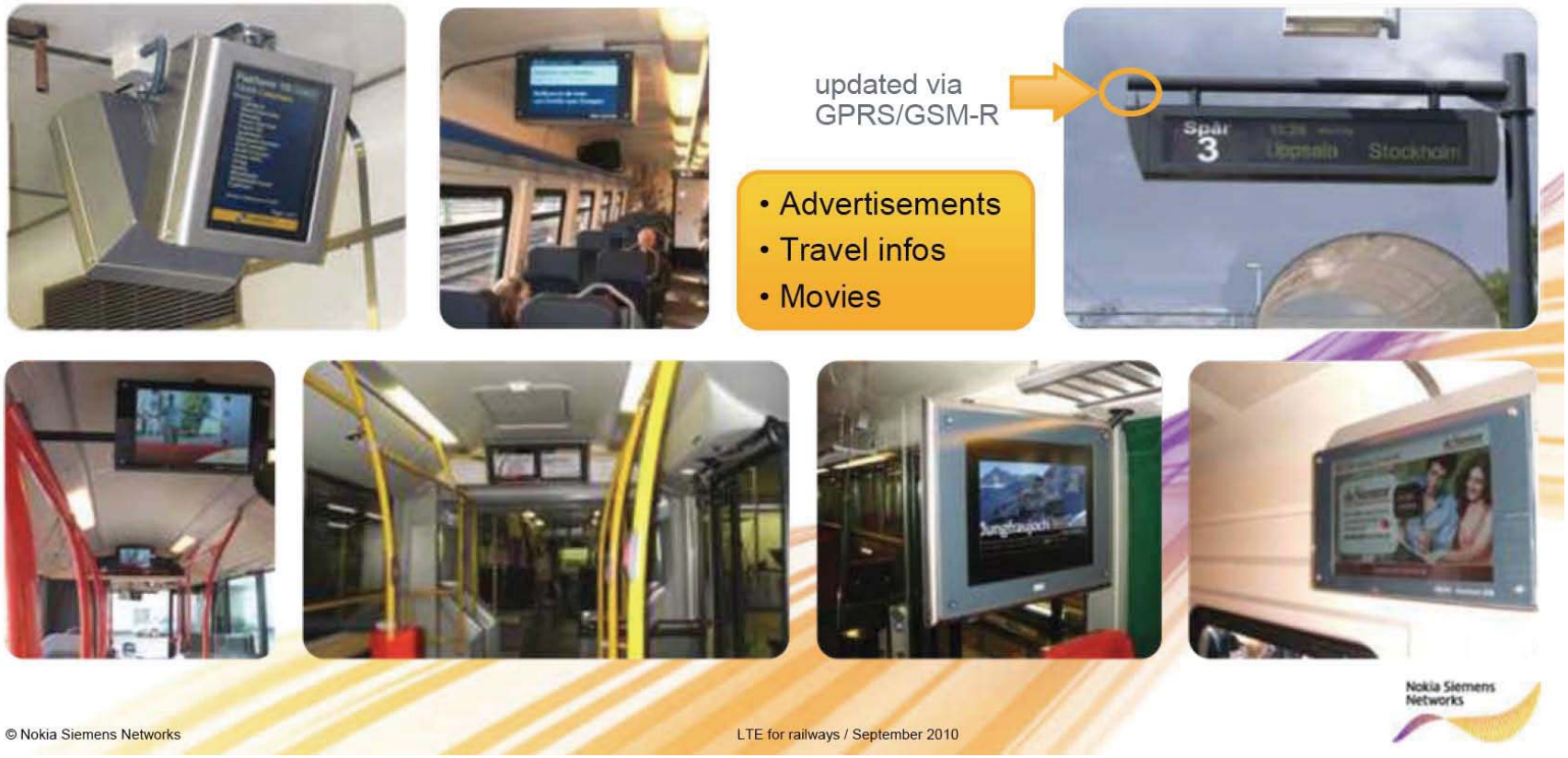





SkyTel

From same publication

# Real-time passenger information for all kind of public transport




SkyTel

From SELEX (Italy) brochure: "The Operational and Mission critical – from narrowband to broadband"

**SELEX Elsag's LTE network solution fulfills the requirement for a broadband mission and operational critical network based on LTE standard. It is totally integrated and interoperable with professional and civil networks.**

## SMART CITY AND TRANSPORTS

Network architectures used in Smart Cities foresee the use of a mix of networked technologies. Wireless broadband communications are among the most frequently used, thanks to their ability to support applications and services on the move. Video streaming, intensive access to data bases and multi-media communications between security operators benefit from SELEX Elsag's LTE solution. The growing importance of the Internet of Things and machine-to-machine communications will increase the use of fast and cost-effective LTE-based deployable solutions.
Both in urban transportation and in high-speed lines, the transmission of reliable data and video communication are becoming increasingly important.

- Reliable broadband connections to support **info-mobility applications, passenger information systems and on-board video surveillance.**
- Network resilience and broadband connections to support **real-time control data and machine-to-machine data.**
- **Broadband data:** live video feed needs to be exchanged between field personnel and control rooms.
- **Integration of networks:** different organizations need to communicate with each other in voice and data both during day-by-day activities and in emergency situations

From: http://www.selexelsag.com/internet/localization/IPC/media/docs/THE-RADIO-COMMUNICATIONS-NEW-PATH.pdf

From publication identified on the right

# ALCATEL-LUCENT LTE-BASED TWC SOLUTION FOR RAILWAY OPERATIONS

Next-generation communication network technologies like LTE will transform the current ICT infrastructure for train-to-wayside communications (TWC). This transformation will lead to new operational service capabilities and improved operational efficiency.

## Why LTE?

The key value propositions of LTE are summarized below:

1. With a user-plane latency as low as 10ms LTE supports a more capable CBTC system, leading to higher efficiency in train operation.
2. Sophisticated QoS built into LTE guaranteed delivery of critical traffic over a multi-service network, leading to OPEX reduction.
3. The all-IP architecture and superior broadband capacity performance of LTE opens up the possibility of supporting new kinds of operational or infotainment services and lowers the integration barrier.
4. As the leading-edge mainstream mobility technology, LTE offers a platform for future evolution and growth. Its strong ecosystem support will deliver the best possible performance–value ratio in the long term.
5. LTE is a commercial off-the-shelf solution (COTS). It does not need to be modified to meet the stringent requirements for carrying mission-critical services.
6. Despite its status as the newest of the 3GPP standards, LTE's evolutionary nature shares the benefits of many of the proven mobility technologies and architectural concepts defined in preceding standards. A January 2013 LTE market summary by the Global Mobile Suppliers Association (GSA) projected that 234 commercial LTE networks would be in place in 83 countries by the end of 2013.*

This & following pages are from:

Alcatel·Lucent

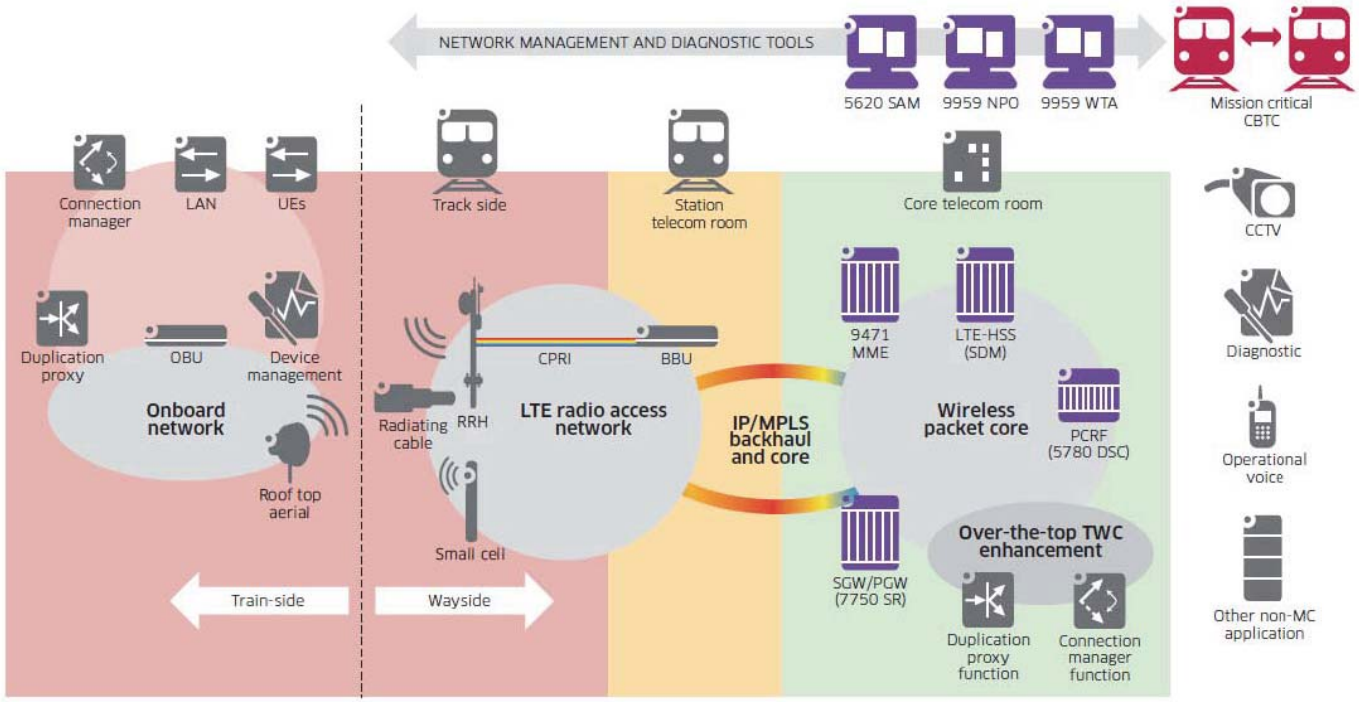
LTE FOR METRO RAILWAY OPERATIONS

UNLOCKING NEW OPPORUNITIES TO OPTIMIZE RAILWAY OPERATIONS WITH LTE-BASED TRAIN-TO-WAYSIDE COMMUNCATIONS TECHNOLOGY

TECHNOLOGY WHITE PAPER

From: http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2013/8272-alcatel-lucent-lte-metro-railway-operations.pdf

Figure 1. Overview of the Alcatel-Lucent LTE-based TWC solution




## Small cell solutions for future railway applications

A small cell solution differs from the traditional macro cell architecture because it offers lower radio power (< 5 W) output that results in smaller cell coverage. It can also integrate the baseband processing unit (BBU) and radio amplifier component within a single unit that is small in dimension (< 20 L) and light enough (< 20 kg) for a single installer to handle. Gigabit Ethernet backhaul is supported by way of a built-in BBU.

Another small cell differentiator is the ability to support self-organizing network (SON) capabilities. These capabilities greatly simplify radio commissioning compared to macro cell commissioning, which traditionally requires highly skilled radio planners and drive testing. With small cell deployments, an installer can be sent to the field, and commissioning can be managed remotely. This could significantly reduce commissioning time and limit disruption of train services.

Continued from previous page- same publication

# OVERCOMING BARRIERS TO SECURING LTE SPECTRUM

Despite many promising benefits of LTE, a key prerequisite for adopting LTE in railway environments is to secure the necessary licensed spectrum.

The demand for LTE spectrum by the public mobile telecom industry is very high. As a result, the expectation is that it would be very difficult for a railway operator to compete with the mobile network operators to secure "sweet spot" frequency bands such as the 800 MHz–2.6 GHz bands.

[Including lower 900 MHz, which is in the standard LTE "Band 8."]*

Alcatel-Lucent believes that a number of options are available for consideration by metro railway operators. For example:

- A metro operator could use LTE 400 MHz, which provides alternative spectrum that can carry mission-critical traffic.
- A metro operator could adopt mobile virtual network enabler (MVNE) role in which it:
  - ¬ Establishes spectrum partnerships with MNOs for leasing spectrum usage rights for DTP tracks, lines and stations
  - ¬ Builds and manages the wireless network to ensure that it meets the key performance indicators (KPI) for railway operations
  - ¬ Resells or leases out spare data capacity to MNOs

This strategy establishes cooperation between MNOs and the metro operator. Both sides can share costs, maximize the investment return and avoid the complexity inherent in deploying multiple wireless infrastructures to fulfill similar needs.

Continued from previous pages - same publication

** SkyTel's M-LMS spectrum is in this spectrum "sweet spot" especially for long railway and other transportation corridors such as the US Northeast Corridor and its spurs.*

Frequencies listed below in blue are *SkyTel* entities' nationwide licenses' frequencies, including in Northeast Corridor. *Together, these are ideal for coverage, redundancy, two-way and one-way broadcast.*

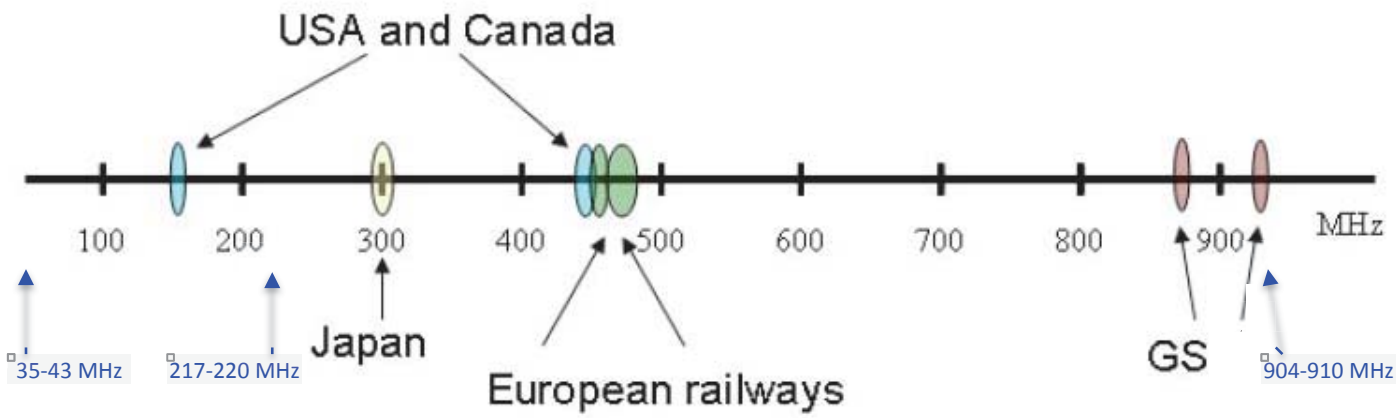



Fig. 5. Worldwide dedicated frequency bands for railway wireless communication services.

Chart above (without the blue items) is from:
http://www.researchgate.net/publication/224116357_Multi-broadcast_communication_system_for_high_dynamic_vehicular_ad-hoc_networks/file/32bfe51248be214110.pd

This describes an *additional* form of wireless for railroad safety. *SkyTel entities' spectrum is very suitable for this, as well.*

From: See next page for paper title and authors. Copy at this link:
http://www.researchgate.net/publication/224116357_Multi-broadcast_communication_system_for_high_dynamic_vehicular_ad-hoc_networks/file/32bfe51248be214110.pd

***Abstract*—The implementation of Safety of Life (SoL) services in transportation systems, e.g. for applications like collision avoidance of vehicles, requires reliable and instantaneous information exchange. In this paper we present the design of an infrastructure-less ad-hoc inter-vehicle communication system that fulfills these requirements with respect to the boundary conditions in the railway environment, where a limited communication range and relatively high speeds of nodes cause the network to be highly dynamic. Moreover, in areas with high user densities the common media access is a challenge due to limited bandwidth and interference from other wireless systems.**

## I. Introduction

STATISTICS of the International Union of Railways (UIC) show, that there are three significant train accidents in Europe every day [1], despite of millions of Euros which have been invested in trackside and in-train safety equipment. Even with Automatic Train Control (ATC) systems like the future European Train Control System (ETCS) a significant amount of accidents cannot be prevented, because they occur between trains and other kinds of obstacles like construction vehicles, construction workers or pedestrians and vehicles on level crossings.

In order to increase safety in railway traffic, a vehicle integrated collision avoidance system similar to the existing ones in maritime or air transportation [2], is proposed. Conceptual this provides a safety overlay level that would take effect in situations that caused most accidents in recent years The advantages are higher safety as well as more efficient use of railways on an international level at low cost and without changes to existing infrastructure and independent of the various railway control mechanisms.

While suitable solutions for the inter-vehicle communication link were developed for the maritime AIS (Automatic Identification System) and the aeronautical TCAS/ADS-B [3] (Traffic Alert and Collision Avoidance System / Automatic Dependent Surveillance - Broadcast), the railway specific boundary conditions necessitate a new design for RCAS and other applications where there are

- (punctually) very high user densities,
- the network dynamic is high due to a relatively short communication range and high user speeds, and
- bandwidth limitation and/or robustness against interfering systems

is mandatory.

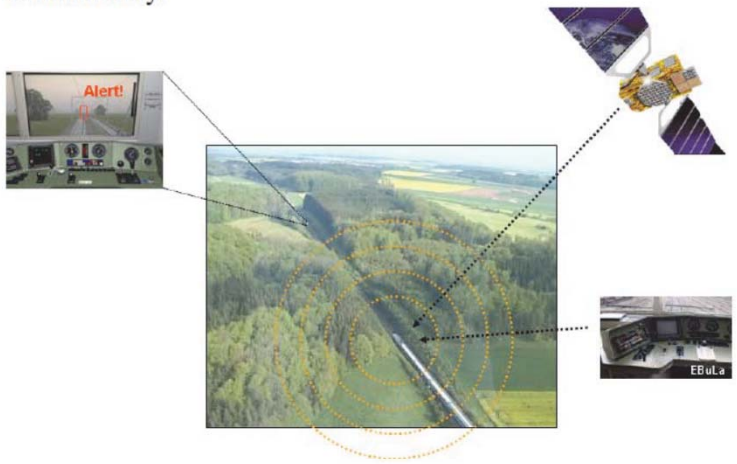



Fig. 1. Principle of collision avoidance based on the broadcast of traffic relevant information among vehicles, illustrated for the railway case.

Continued from previous page.*

## III. RCAS Architecture

On board of each rail vehicle an intelligent RCAS unit is foreseen, comprising sensors, a transceiver and a processor unit as shown in Fig. 2. The sensors are used for accurate track resolving localization. A combination of GNSS (Global Navigation Satellite System) receiver, odometer and eddy current sensor can be used [5]. The last one not only improves the accuracy along the track by detecting rail clamps, but also allows identification of switches and the switch stand by unique signatures. Aided by an electronic map this guarantees precise rail selective PVT information even in tunnels, under roofs of train stations and in shunting yards with many parallel tracks.

Together with train specific parameters like its dynamic behavior, the PVT data is broadcasted via the RCAS communication unit. As well each unit receives messages from nearby trains and analyses this data together with its own status in the RCAS algorithm to identify collision threats and give warnings or even braking commands to the

TABLE II

COMPARISON OF NETWORK DYNAMIC AND NODE DENSITY FOR COLLISION AVOIDANCE APPLICATION IN DIFFERENT TRANSPORTATION SYSTEMS

| Transport system | Min. comm. range | Maximum velocity | Topological network dynamics | Max. number of nodes within range |
|---|---|---|---|---|
| Ships - AIS SOTDMA | 40 km | 60 km/h | 1,5 $h^{-1}$ | 75 |
| Airplanes - TCAS ALOHA | 56 km | 1000 km/h | 16 $h^{-1}$ | 30 |
| Trains - RCAS COMB | 5 km | 200 km/h | 40 $h^{-1}$ | 250 |

Because of the limited channel resources and the high node density together with the high network dynamic it was necessary to develop a new class of MAC protocols called COMB that we published in [17]. This Cell based Orientation aware MANET Broadcast MAC layer utilizes the information of the nodes about their location, direction, speed, and precise timing. The world map is divided into virtual hexagonal cells as illustrated in Fig. 8. Neighboring cells are distinguished by different spreading codes and

This and previous pages are excepts from:

**Multi-Broadcast Communication System for High Dynamic Vehicular Ad-hoc Networks**

Andreas Lehner, Cristina Rico-García, Eugen Wige, and Thomas Strang,
*Institute for Communications and Navigation, German Aerospace Center DLR*

*SkyTel entities' nationwide plan has, as a core application – high accuracy position, timing and navigation (HA PNT). We have an ideal combination of 3-bands of spectrum for this, using broadcast, mobile peer-peer, and two-way modes, and delivery of constant Network RTK GNSS correction data for sub-decimeter accuracy combined with onboard INS, etc. HA PTN will improve even further the type of railroad (trains) RCAS described above. ("RCAS" = Railroad Collision Avoidance System)*

- 3 -

# SkyTel

*AMTS* 217 - 220 *MHz*
*M-LMS* 904 - 910 *MHz*
*& Lowband* 35 / 43 *MHz*

For nationwide
smart transport, energy and environment systems
which can include ARW

# SkyTel FCC Licenses

**900 MHz wide-block M-LMS**, ~80+% of US, 6 MHz total, held by:
Telesaurus Holdings GB LLC, Skybridge Spectrum Foundation
(Renewal applications pending)

**900 MHz** Part 22 and MAS, ~99% of the US, held by:
Skybridge Spectrum Foundation, V2G LLC, Intelligent Transportation & Monitoring Wireless LLC

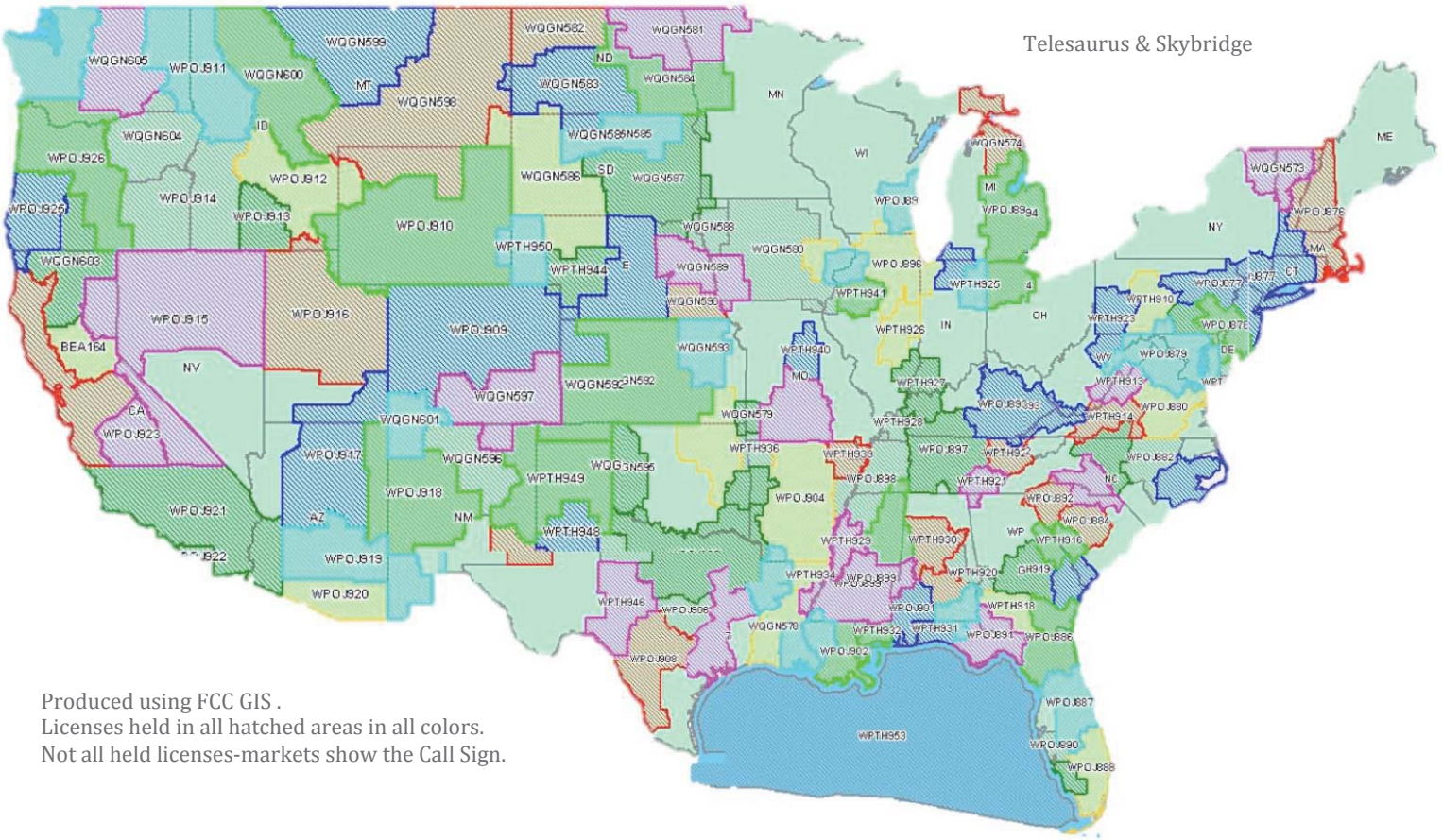
**200 MHz AMTS**, ~95% of US, 1-2 MHz total, held by:
Environmentel LLC, Verde Systems LLC, Intelligent Transportation & Monitoring Wireless LLC,
Skybridge Spectrum Foundation
(Potentially others under pending FCC proceedings.)

**43 and 35 MHz**, ~99% of US two-way, and 100% one-way, 300-600 kHz total, held by:
V2G LLC, Environmentel LLC, Intelligent Transportation & Monitoring Wireless LLC,
Skybridge Spectrum Foundation

The licenses described herein may be confirmed via the FCC's online databases by going to the following link, clicking on the "Advance License Search" section and then entering in the Licensee's name in the licensee-name field. http://wireless2.fcc.gov/UlsApp/UlsSearch/searchLicense.jsp

Following pages do not further describe the MAS and 220 MHz licenses: see FCC ULS.

M-LMS A-block Licenses, *6 MHz* bandwidth in lower *900 MHz*. See preceding page. This spectrum is within 3GPP *LTE Band 8*.

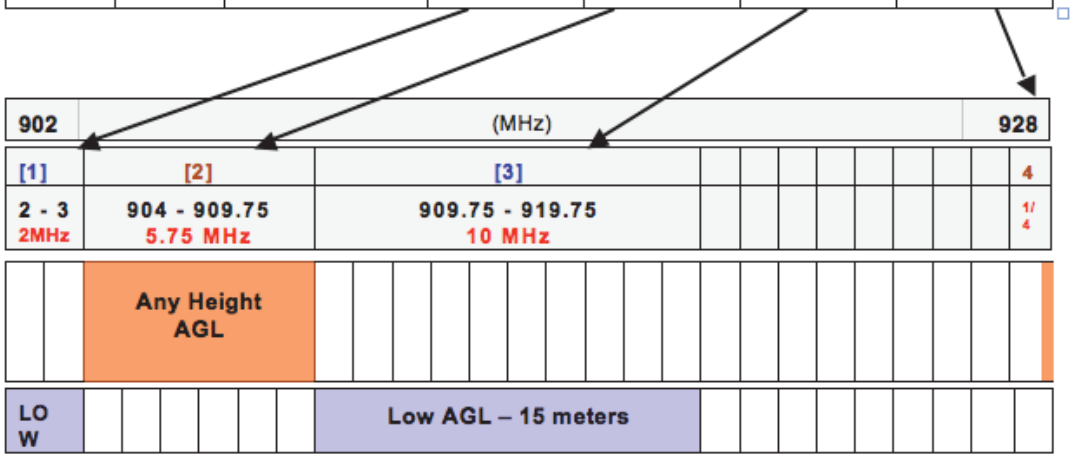



Produced using FCC GIS .
Licenses held in all hatched areas in all colors.
Not all held licenses-markets show the Call Sign.

Note: below depicts the M-LMS and N-LMS sub bands. We do not have to use the channelization depicted in the second table below. We can use any channelization.

## LMS Spectrum

| AGL Max | ERP Max | Spectrum | [1] N-LMS | [2] M-LMS A-block Wide Subband | [3] N-LMS | [4] M-LMS A-block Narrow Subband |
|---|---|---|---|---|---|---|
| m | W | MHz | Gov partner | Held | Gov partner | Held |
| | | | | | | |
| 15 | 30 | 902 – 904 | N | | | |
| Any | 30 | 904 – 909.75 | | M | | |
| 15 | 30 | 909.75 – 919.75 | | | N | |
| | | Not Available | | | | |
| Any | 300 | 927.75 – 928 | | | | M |




http://www.scribd.com/doc/36614169/Sky-Tel-Atlis-900-200-40-MHz-for-Smart-Transport-Energy-Environment-V3-9-10-Public#download

Use of TD-LTE in this M-LMS spectrum is described in a study funded by SkyTel by Dr. Nishith Tripathi, submitted to the FCC, a copy of which is here: http://www.scribd.com/doc/104580013/LTE-for-M-LMS-900-MHz-for-Intelligent-Transportation-Systems-N-D-Tripathi-Aug-2012

SkyTel plans to use *TD-LTE* in this "LMS" spectrum.

Telesaurus Holdings GB LLC and Skybridge Spectrum Foundation hold M-LMS A-Block licenses in the areas depicted on the following map.

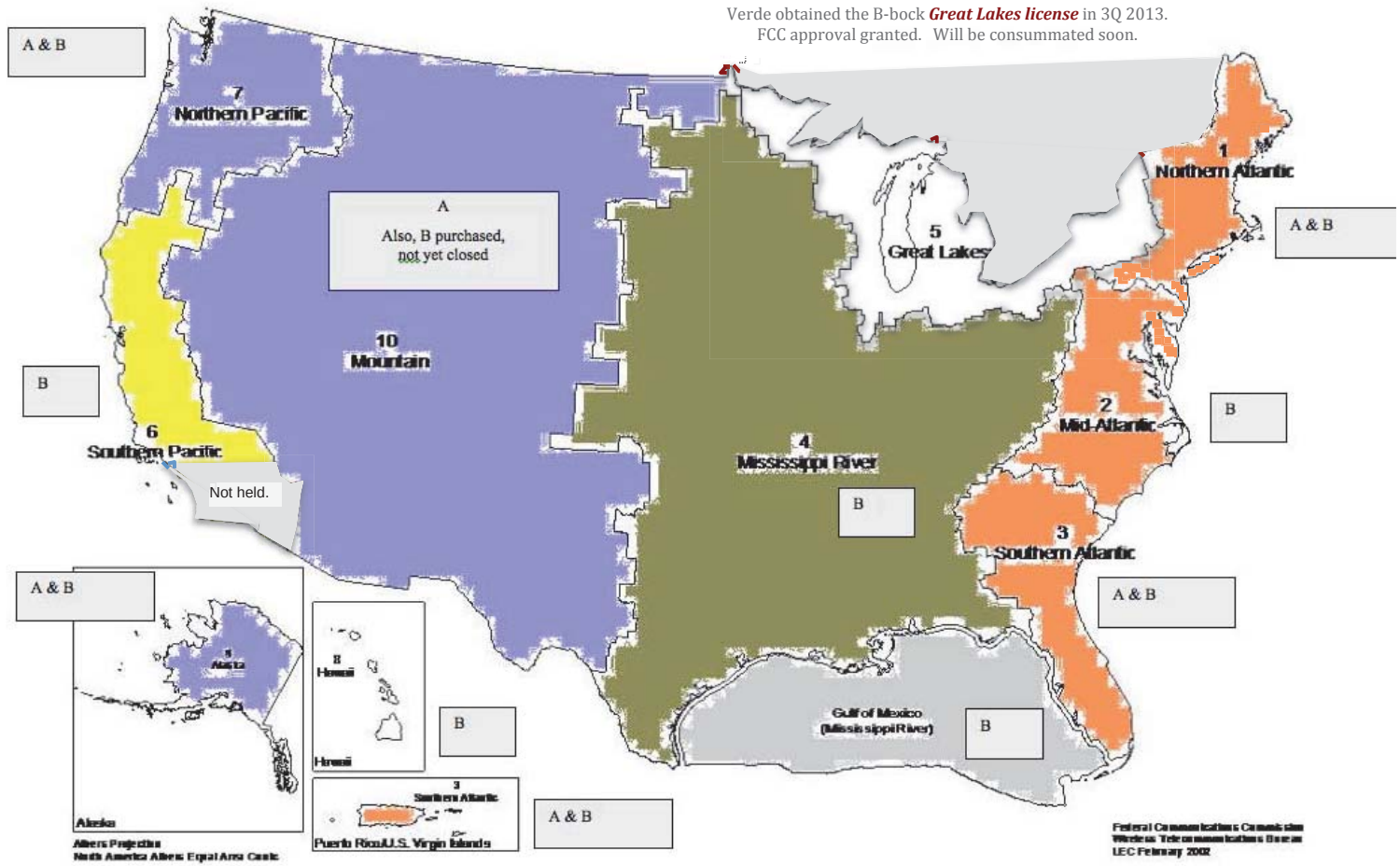
In joint ventures with State and/ or local government, Skybridge may also obtain use of FCC licenses for any region in which the hold M-LMS licenses for N-LMS spectrum depicted above, as well as in the other regions.

The SkyTel entities may also use substantial amounts of 5.9 GHz DSRC spectrum, in the range of 20-30 MHz, under Part 90, Subpart M (this is the sister ITS band to LMS). Cisco bought an Australian company advancing

Among other uses: vehicle to vehicle, and vehicle to roadside (in dual mode with other spectrum indicated above), but also point-to-point backhaul (5.9 GHz, in P-t-P use, matches in distance LMS in mobile use).

AMTS Licenses, *1 MHz* bandwidth in each block, in lower *200 MHz*.

Licensees: Environmentel, Verde Systems, Skybridge Spectrum Foundation, and Intelligent Transportation…Wireless.

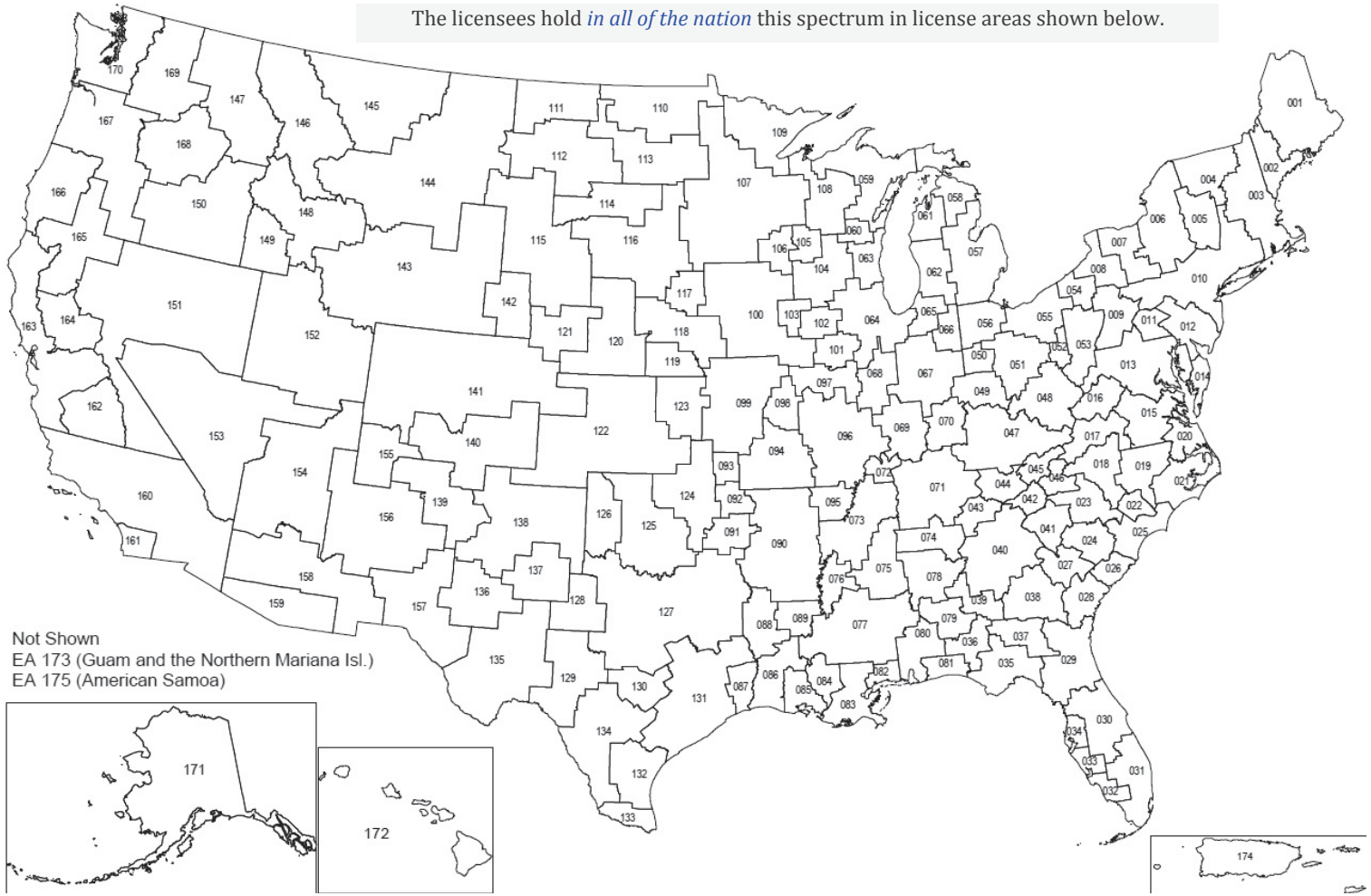



Note: some of the spectrum (one half or less of total ) in parts of market areas 1 and 7 have been sold-assigned to power utilities (as of 1Q 2013).

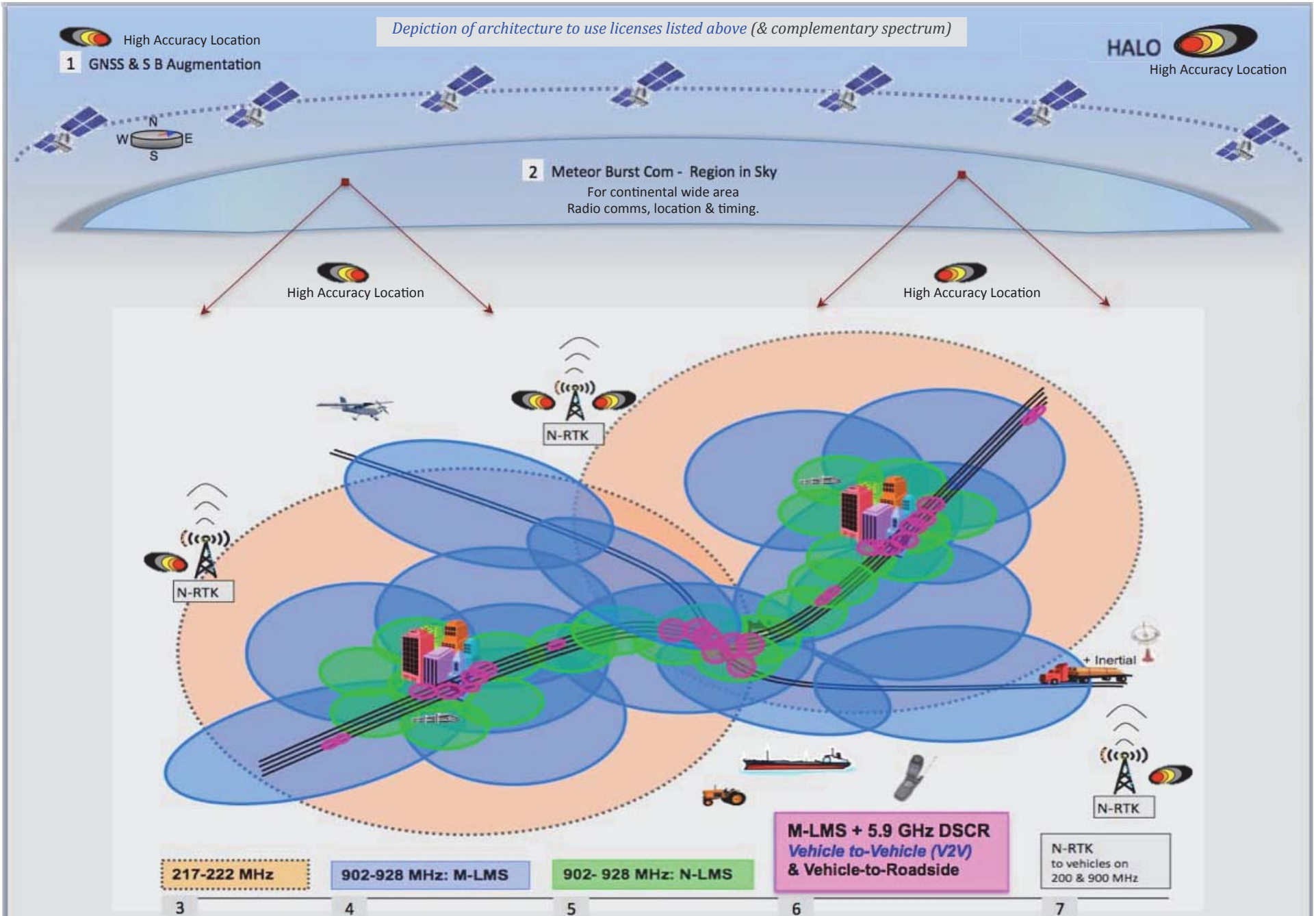
~ 4,000 *35 MHz and 43 MHz* licenses, *20 kHz* in each, ~*300-600 kHz total,* in all parts of the US.

Licensees: V2G, Skybridge Spectrum Foundation, Environmentel, Intelligent Transportation…Wireless LLC.

The licensees hold *in all of the nation* this spectrum in license areas shown below.



*Depiction of architecture to use licenses listed above (& complementary spectrum)*




SkyTel

Source: Skybridge & affiliates